SOLUBLE IRON DEPOSITION UNDER CMIP6 SCENARIOS

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Air-sea Chemical Fluxes : Impacts on Biogeochemistry and Climate

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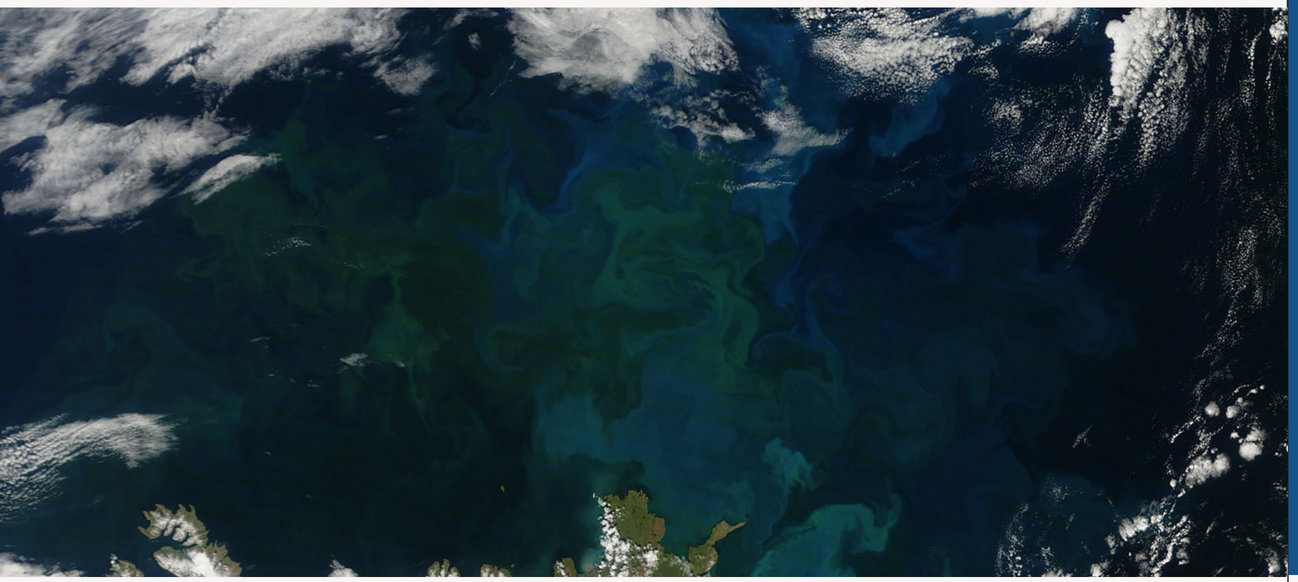

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The atmospheric Fe cycle

Ocean productivity (specially in regions kown as HNLC regions) **relies upon bioavailable Fe** for photosynthesis, respiration, and nitrogen fixation, which makes the **Fe biogeochemical cycle a key modulator of the ocean's ability to uptake atmospheric CO2.**

1

IRON EMISSIONS

- Mineral Dust (95%)
- Combustion (5%)

2

ATMOSPHERIC PROCESSING OF IRON

3

DEPOSITION OVER OPEN OCEAN

Implementation in EC-Earthv3

(Myriokefalitakis et al. in prep)

1

Primary emissions of Fe associated with mineral dust:

- **Dust mineralogical composition** (Claquin et al. (1999) soil mineralogy dataset).
- $$Fe_{emi} = Dust_{emi} \cdot \sum_{i=1}^{N} f_{mineral_i} \cdot f_{Fe_i}$$ (Nickovic et al., 2013)

↓

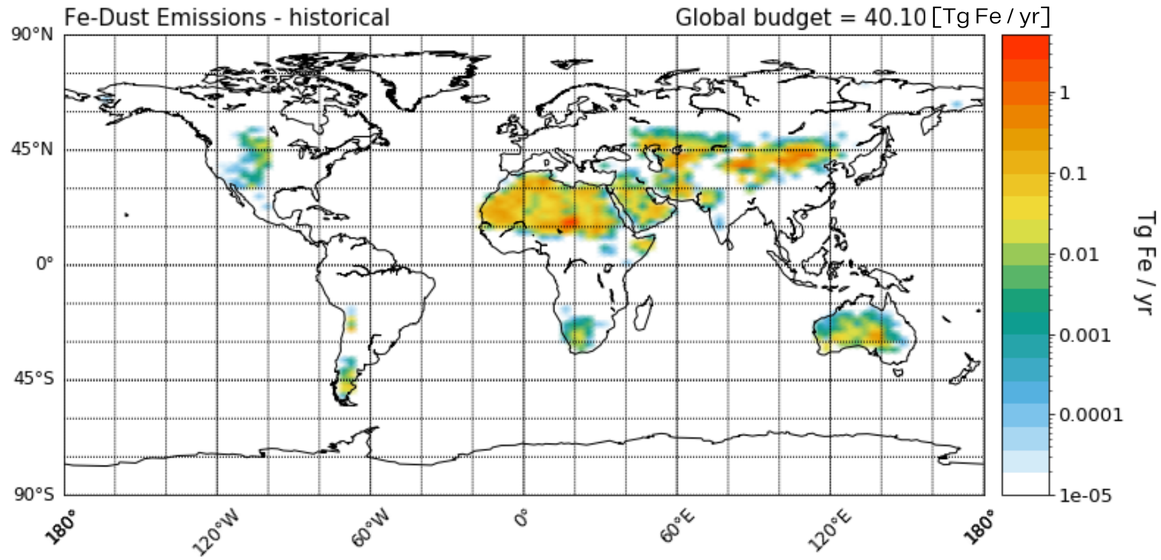
Explicit accounting for key minerals during the dissolution process.

2

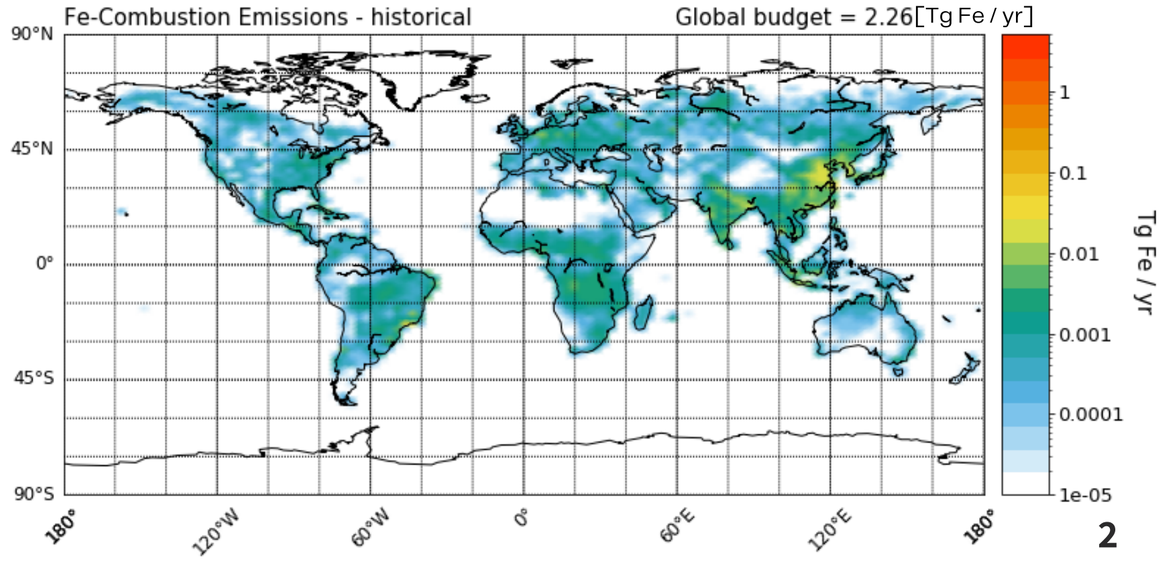
Primary emissions of Fe associated with combustion aerosols (anthropogenic & biomass-burning) .

- **Fe:BC & Fe:OC factors** based on emission estimates (Ito et al. 2018) are applied for each of the emission sectors in CMIP6 emission dataset.

Fe–Dust Emissions



Fe–Combustion Emissions



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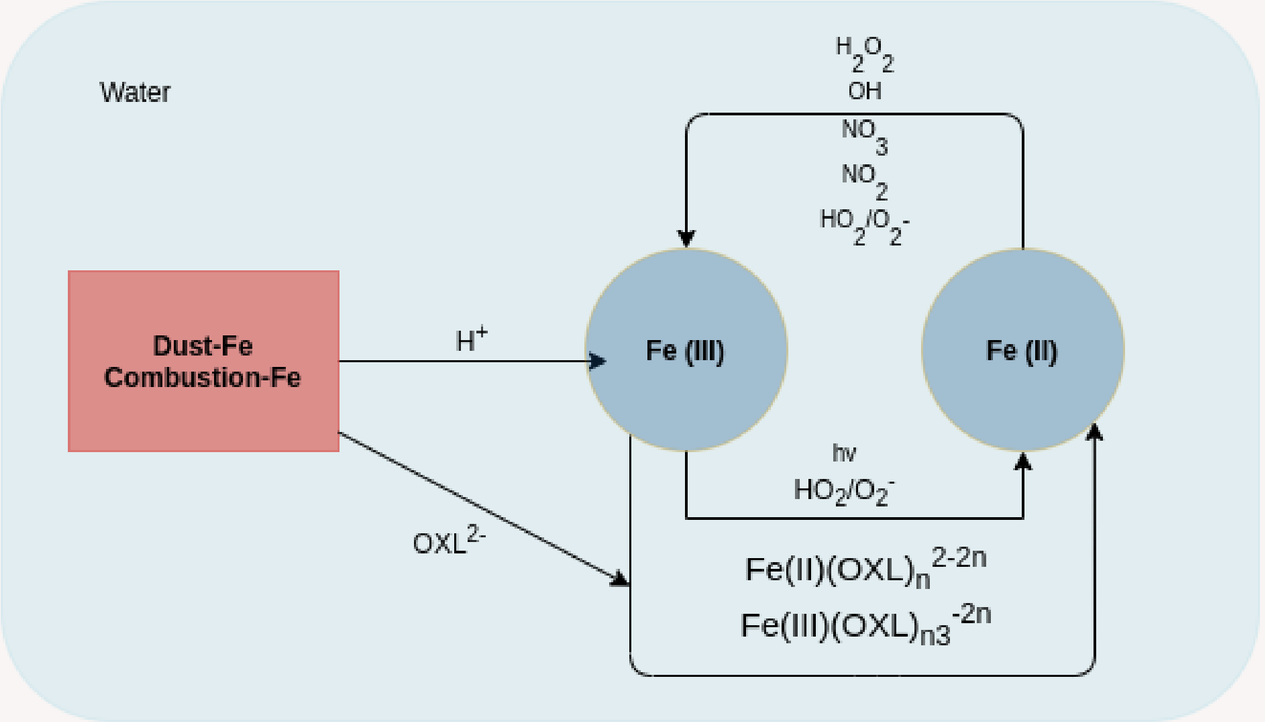
3

Atmospheric processing of Fe, explicit solubilization mechanism treated as a kinetic process accounting for:

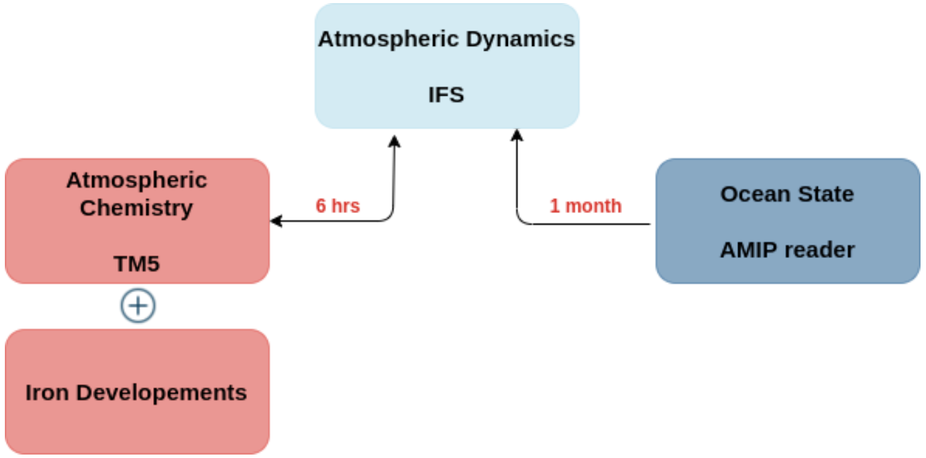
1) Proton-promoted dissolution (atmospheric acidity - ISORROPIA II (Fountoukis and Nenes, 2007))
2) Oxalate-promoted Fe dissolution (with oxalate calculated on-line)
3) Photo-reductive dissolution.



Experimental Setup

30-year long time-slice experiments with fixed sea surface temperature (sst) and sea ice concentration (sic) (feedbacks between the atmosphere and the ocean are not considered)

IFS coupled with TM5 at standard resolution:



				sim. years / members
Future Scenarios (2070-2099)	SSP3-7.0	SST/SIC clim. 7-member-CMIP6 30-year	CMIP6-ScenarioMIP emissions clim.	1/30
	SSP2-4.5	SST/SIC clim. 7-member-CMIP6 30-year	CMIP6-ScenarioMIP emissions clim.	1/30
	SSP1-2.6	SST/SIC clim. 7-member-CMIP6 30-year	CMIP6-ScenarioMIP emissions clim.	1/30
Present (1985-2014)	Historical	SST/SIC clim. 7-member-CMIP6 30-year	CMIP6-ScenarioMIP emissions clim.	1/30
	AMIP			30/1
Preindustrial (1850)	Pre-industrial	SST/SIC clim. 30 year control run	fixed CMIP6 1850 emissions	1/30

SELECTED CMIP6 SCENARIOS

SSP1-2.6:

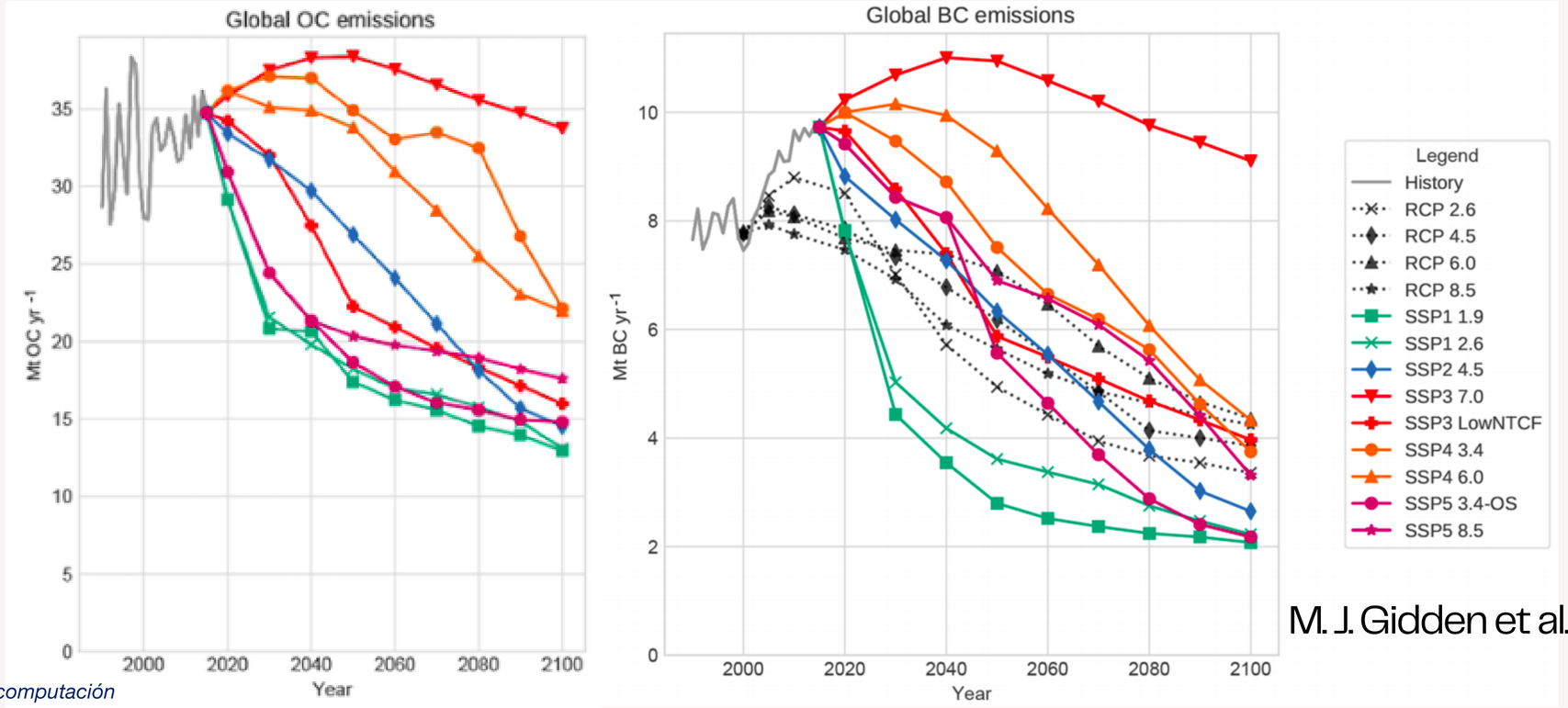
Optimistic and sustainable pathway, that lies in the low end of the range of future forcing pathways and NTFC emissions

SSP2-4.5:

Business as usual scenario that falls in the medium part of the range of future forcing pathways and NTCF emissions.

SSP3-7.0:

Medium to high end of the range of future forcing pathways with high near-term climate forcers (NTCF) emissions.

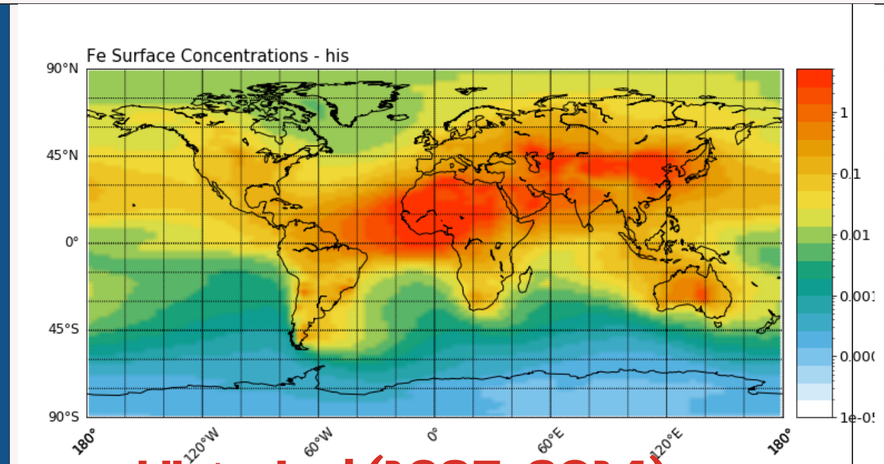


M. J. Gidden et al. 2019

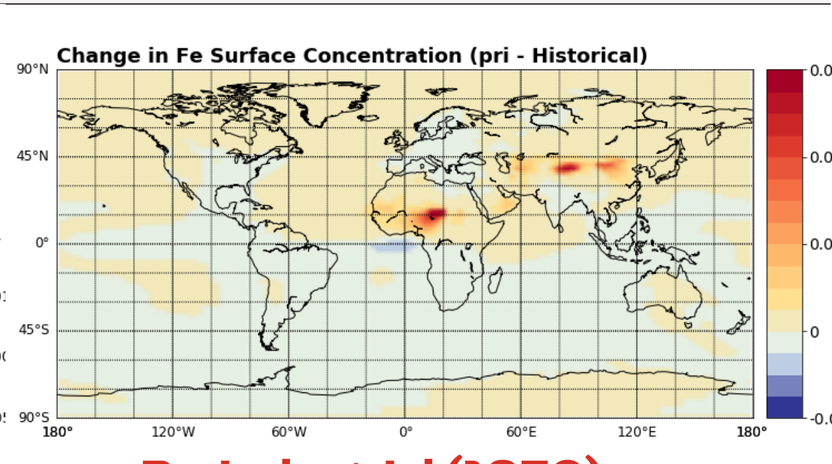
Results under CMIP6 scenarios

IRON SURFACE CONCENTRATION

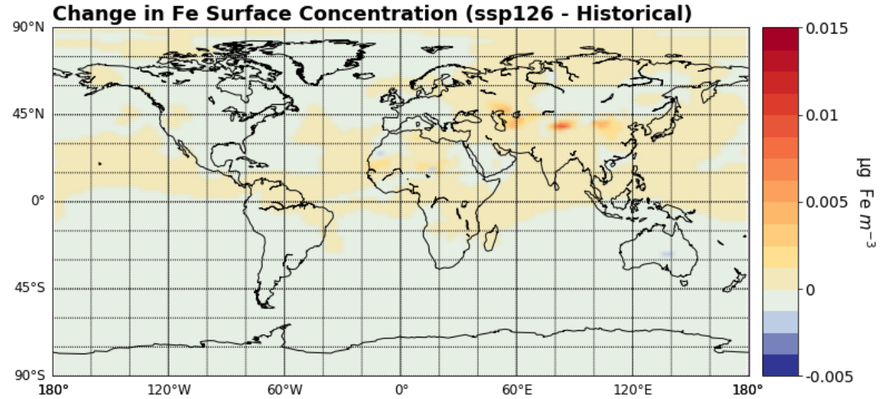
- Annual Mean budget [Tg Fe / yr] for the historical (1985-2014) sim.
- Differences between the other sim. and the historical (1985-2014) sim.



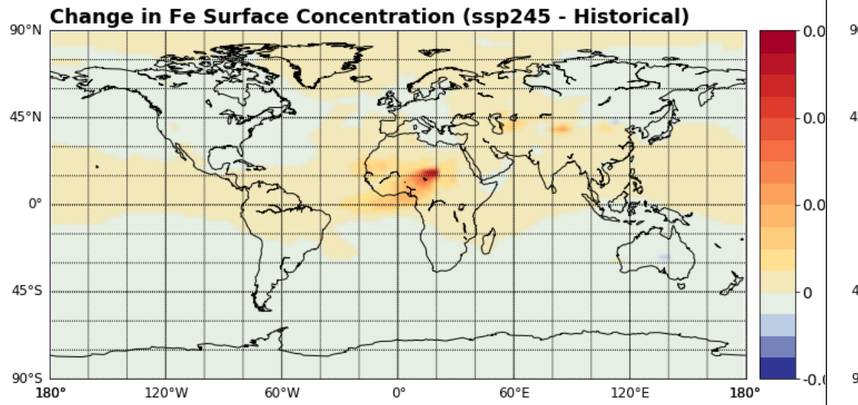
Historical (1985–2014)



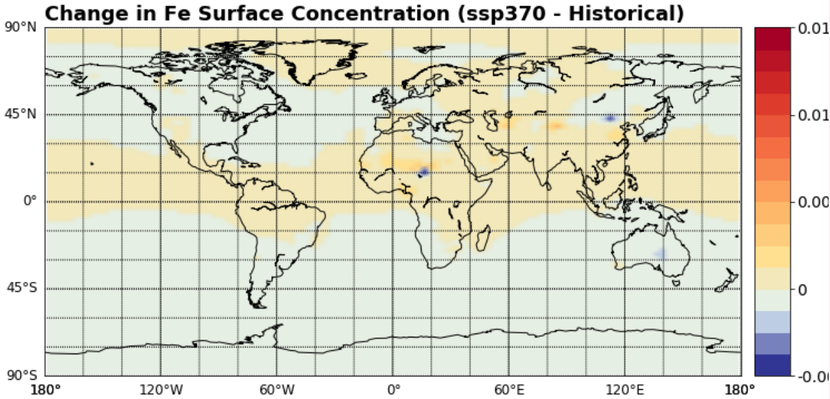
Preindustrial (1850)



SSP1–2.6 (2070–2099)



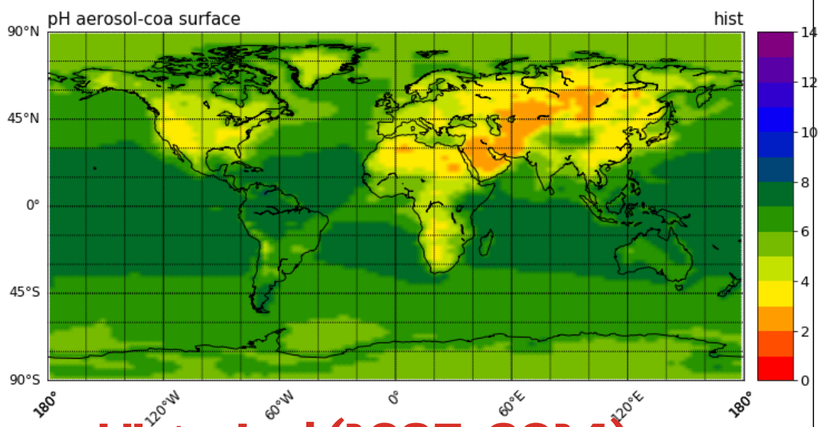
SSP2–4.5 (2070–2099)



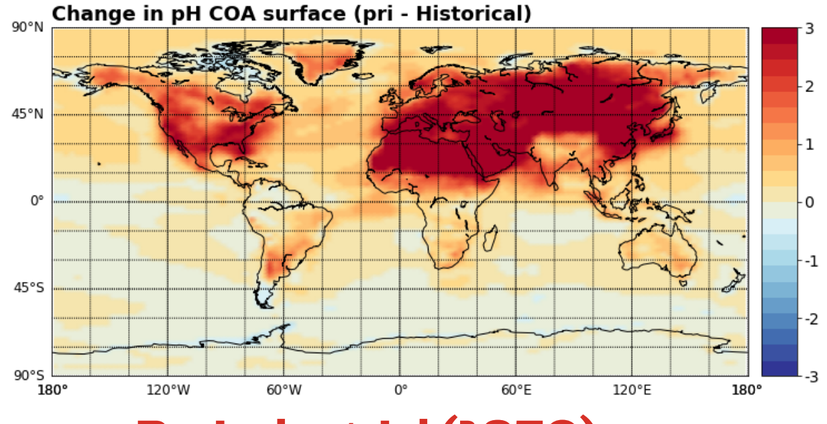
SSP3–7.0 (2070–2099)

AEROSOL COARSE PH - SURFACE

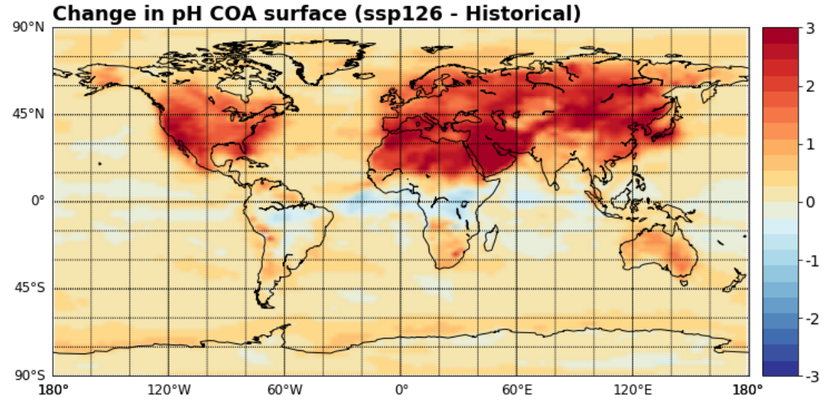
- Annual Mean budget for the historical (1985-2014) sim.
- Differences between the other sim. and the historical (1985-2014) sim.



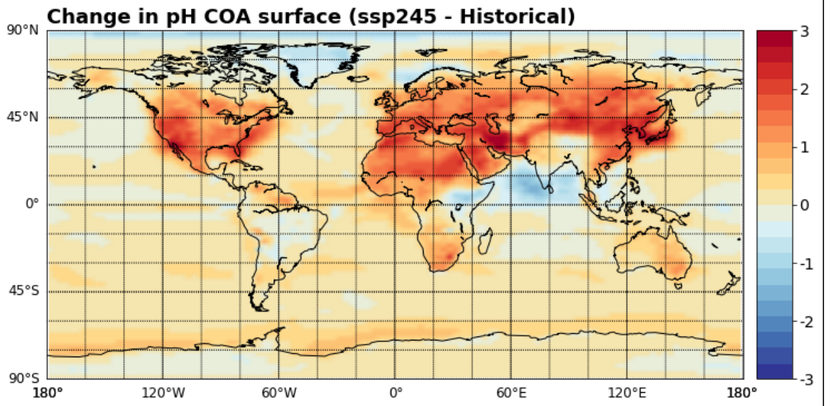
Historical (1985–2014)



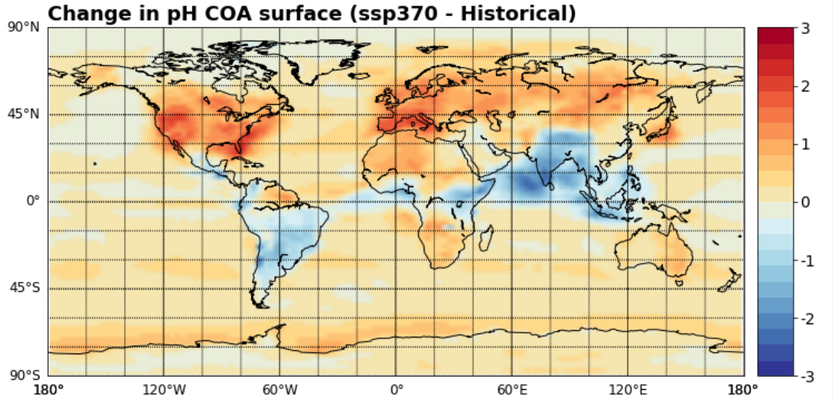
Preindustrial (1850)



SSP1–2.6 (2070–2099)



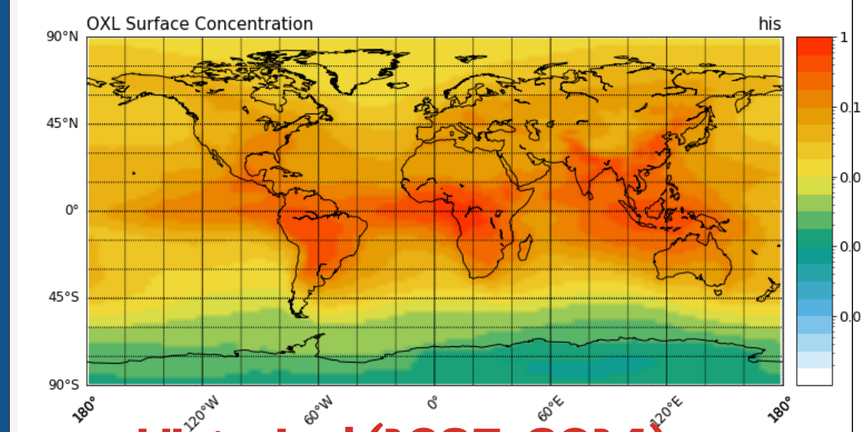
SSP2–4.5 (2070–2099)



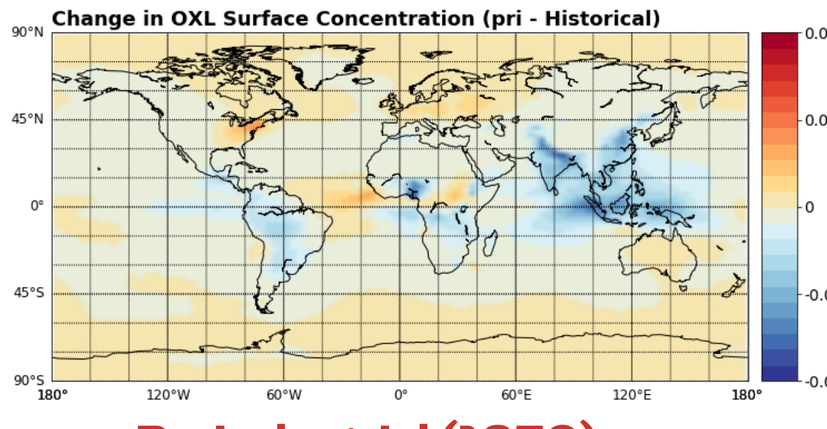
SSP3–7.0 (2070–2099)

OXALATE SURFACE CONCENTRATION

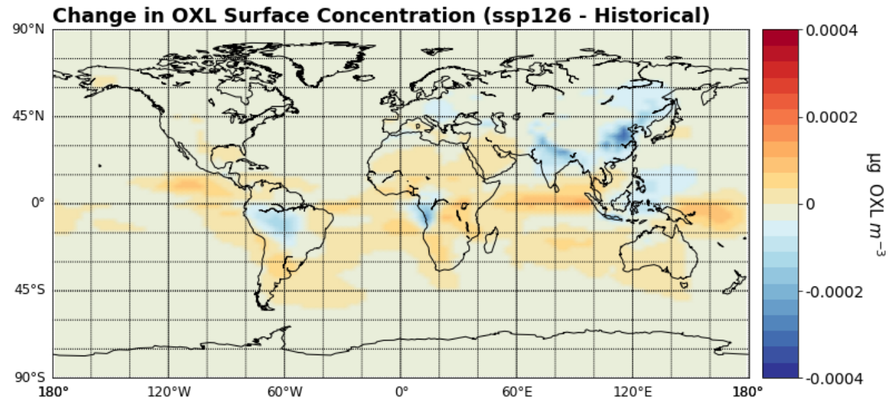
- Annual Mean budget [Tg OXL / yr] for the historical (1985-2014) sim.
- Differences between the other sim. and the historical (1985-2014) sim.



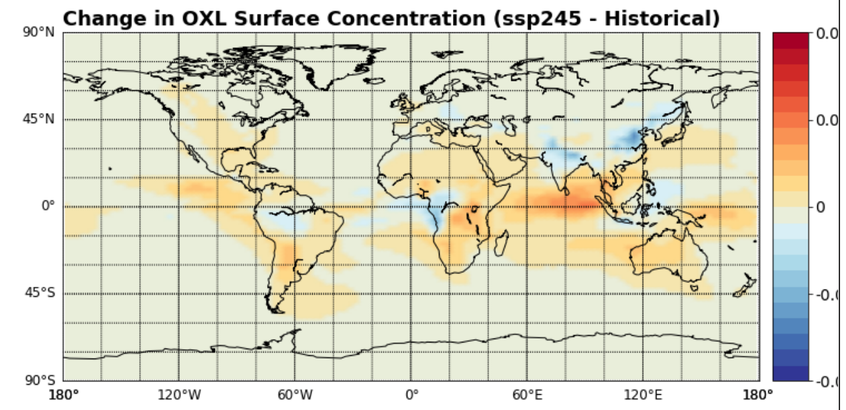
Historical (1985–2014)



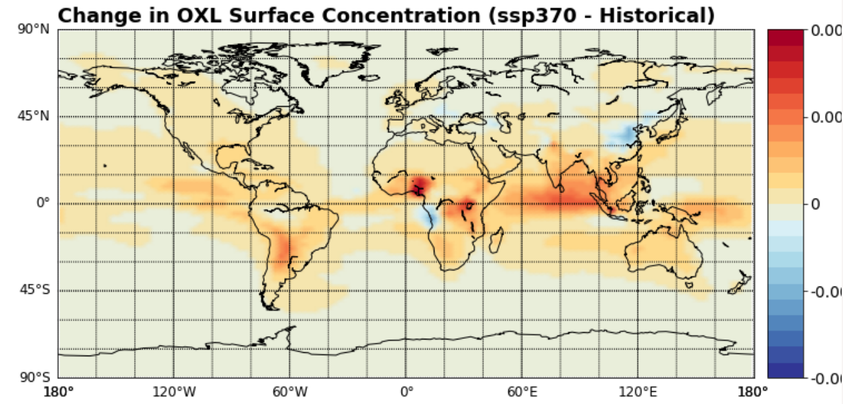
Preindustrial (1850)



SSP1–2.6 (2070–2099)



SSP2–4.5 (2070–2099)

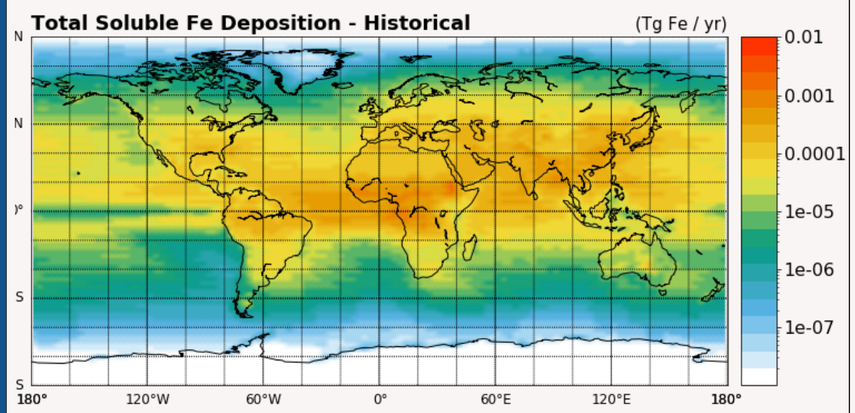


SSP3–7.0 (2070–2099)

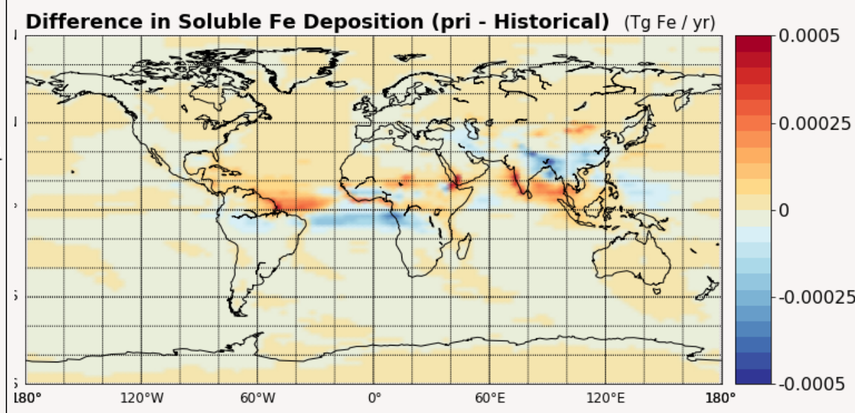
Soluble iron deposition under different CMIP6 scenarios

SOLUBLE IRON DEPOSITION

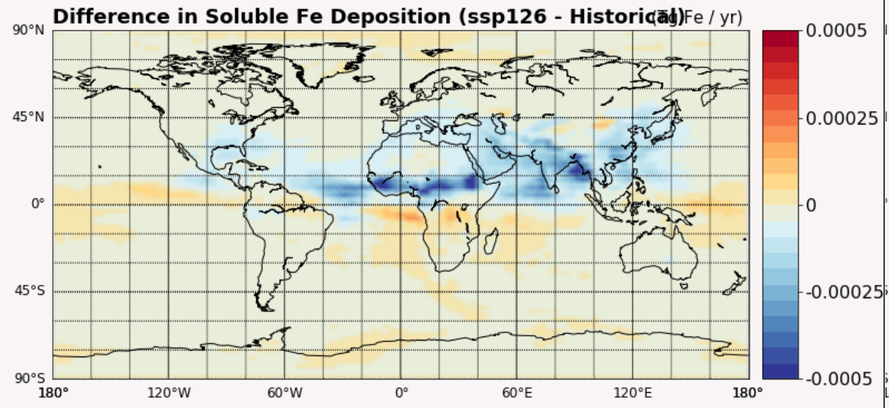
- Annual Mean budget [Tg Fe / yr] for the historical (1985-2014) sim.
- Differences between the other sim. and the historical (1985-2014) sim.



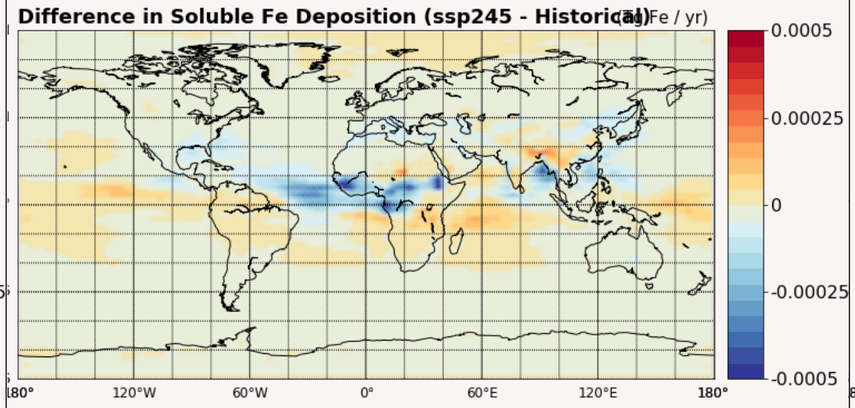
Historical (1985–2014)



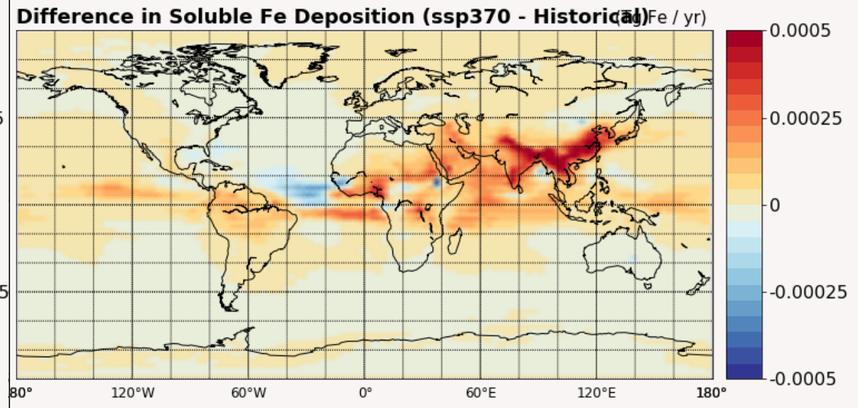
Preindustrial (1850)



SSP1–2.6 (2070–2099)

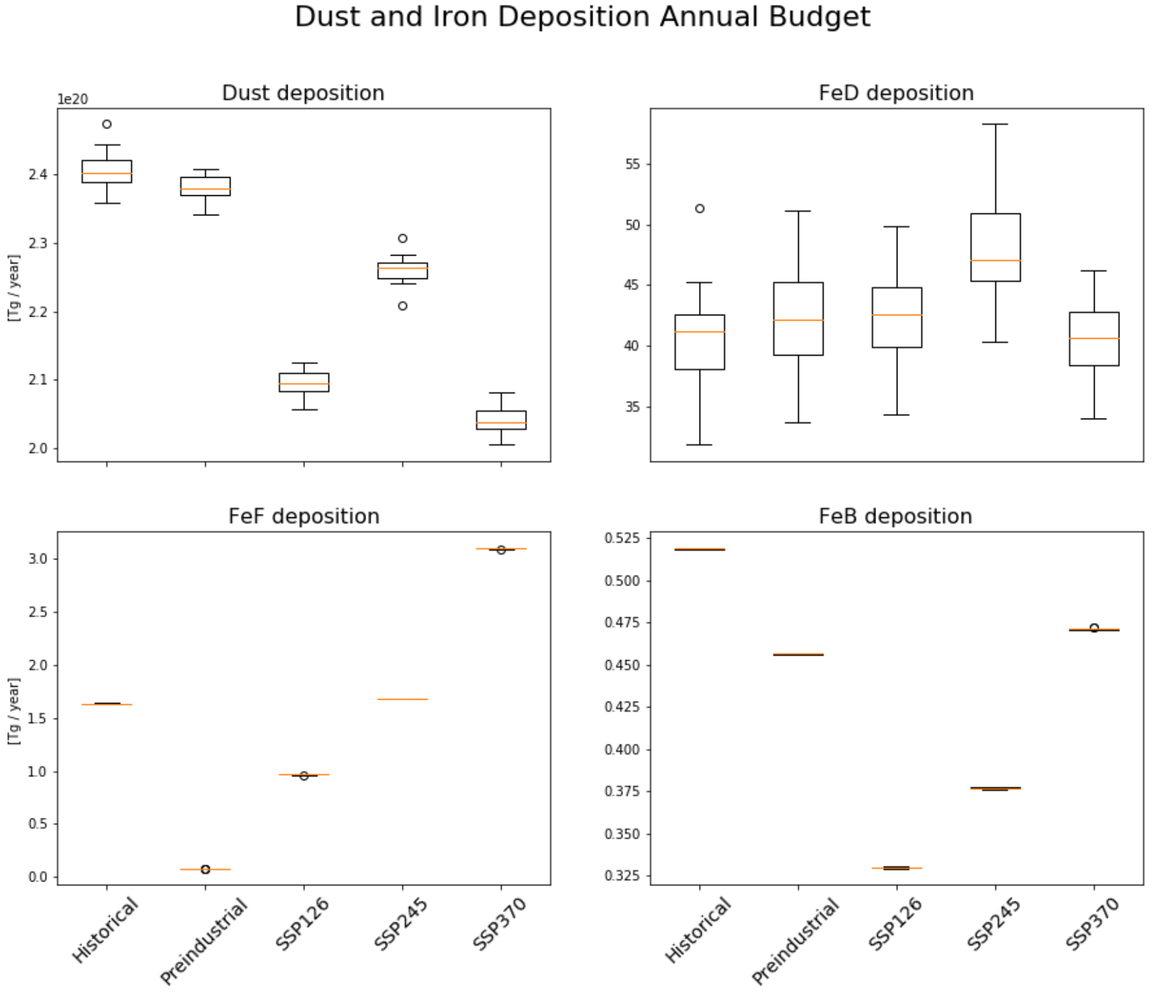


SSP2–4.5 (2070–2099)

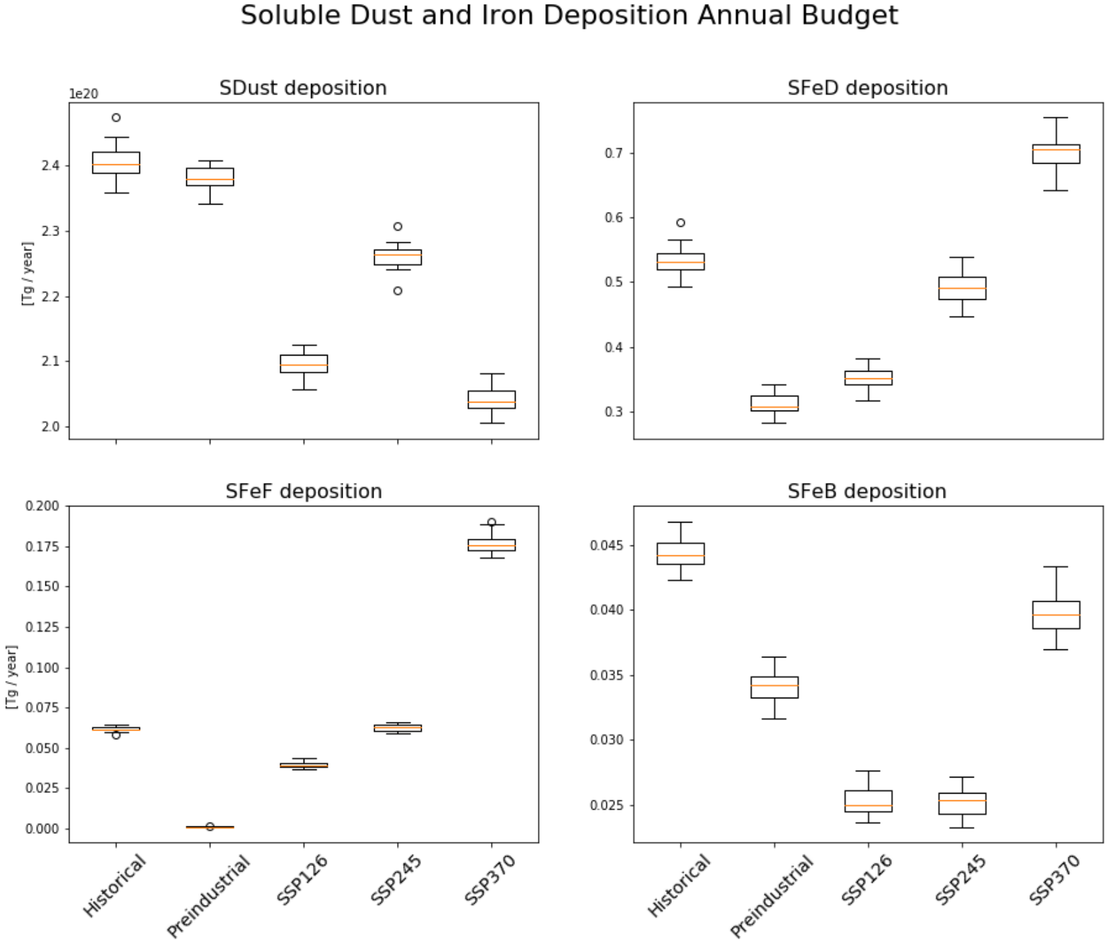


SSP3–7.0 (2070–2099)

Global annual Fe-deposition budgets



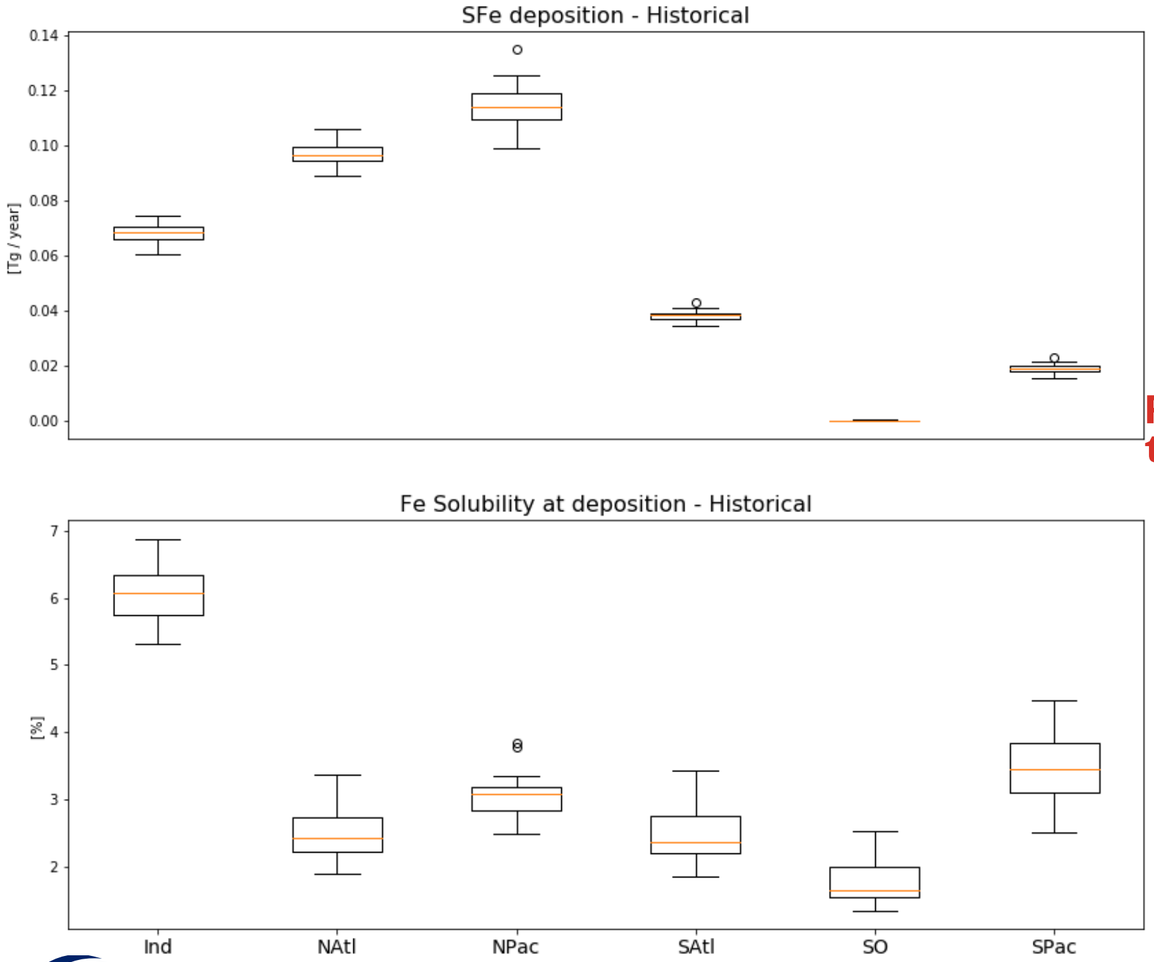
Total Fe deposition budgets



Soluble Fe deposition budgets

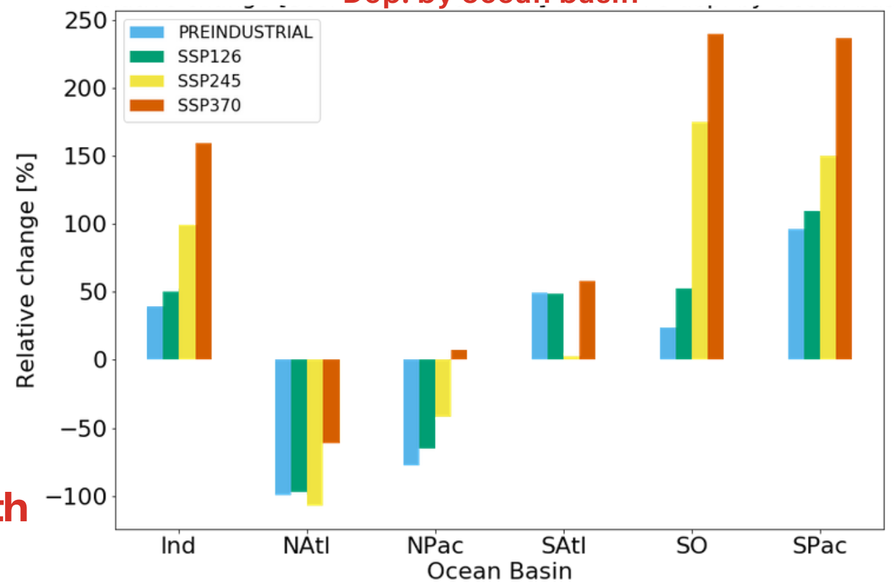
Soluble-Fe deposition budgets by ocean basin

Soluble Fe deposition budgets (up) and solubility (bottom) for the Historical run

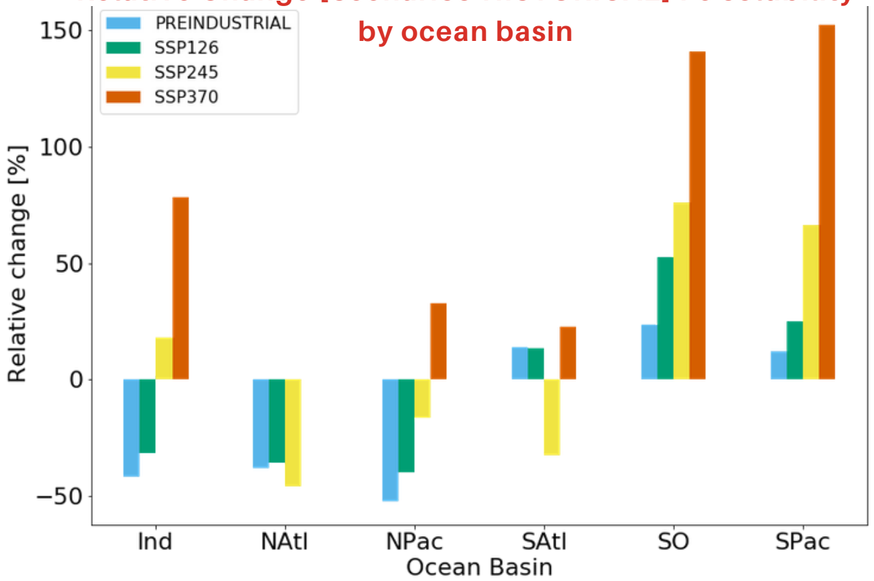


Relative changes with the other scenarios

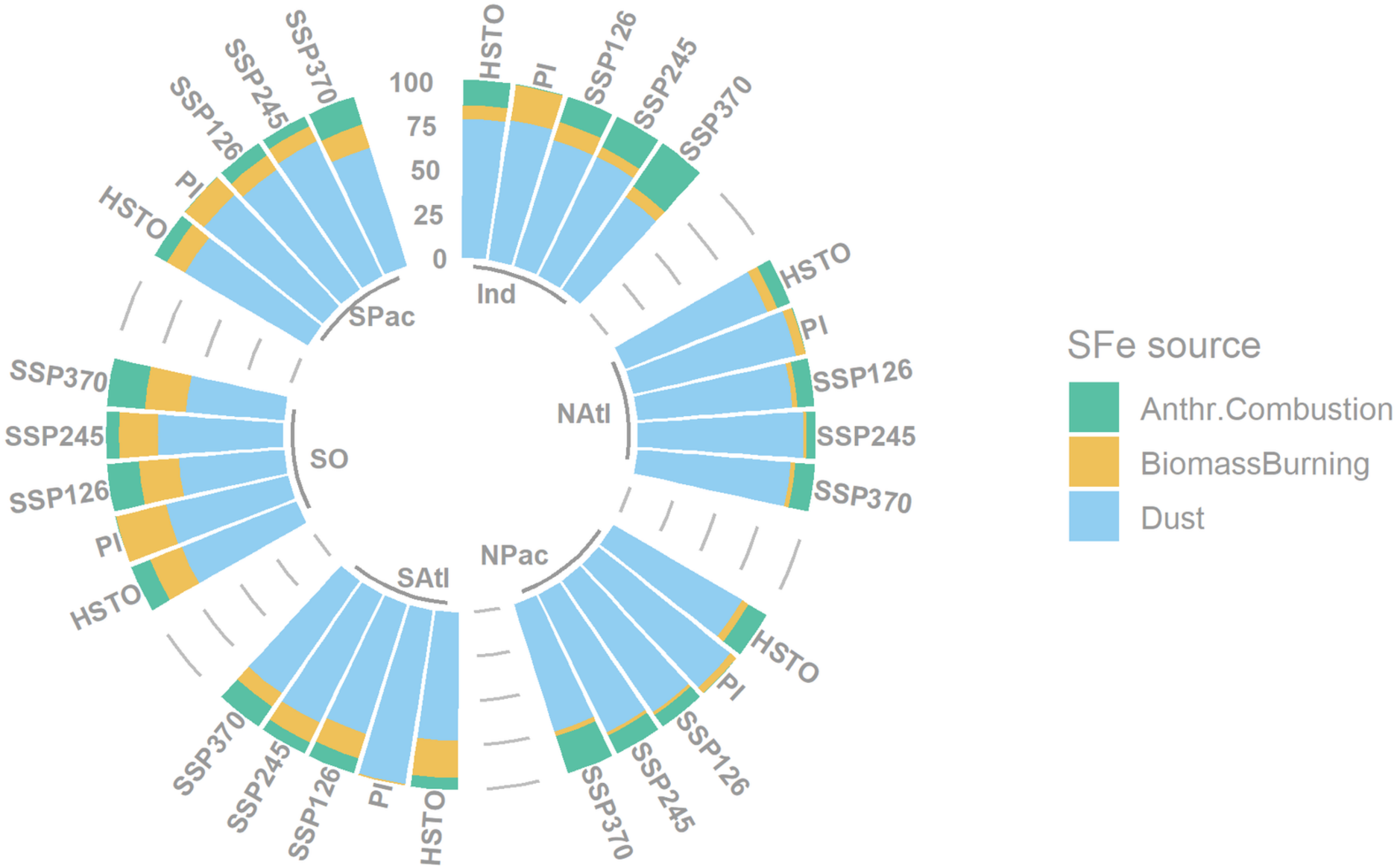
Relative Change [Scenarios-HISTORICAL] Soluble Fe Dep. by ocean basin



Relative Change [Scenarios-HISTORICAL] Fe solubility by ocean basin

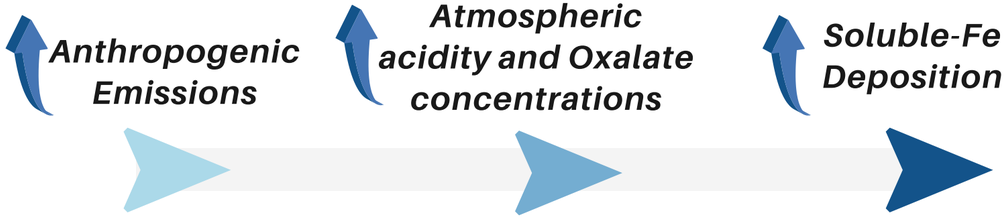


Source contribution to Soluble-Fe deposition by ocean basin



Conclusions

We have set a promising model baseline for EC-Earthv3 accounting for an explicit representation of the atmospheric iron cycle that allows us the quantification of soluble iron deposition under a range of scenarios.



- Soluble-Fe deposition substantially rises for SSP3-7.0, +50% with respect to present-time.
- For SSP1-2.6 & SSP2-4.5 we estimate a decrease in soluble Fe-deposition compared to present time (-17% and -39% respectively).

Future Plans

This work will produce new soluble **Fe deposition fields** that could be used as input for the **ocean biogeochemical component of the next generation ESMs** (e.g., EC-Earth4)

We plan further **studies dealing with uncertainties that have not been discussed** (e.g., future land surface changes over dust emission or the use of different biomass-burning emission databases)

This work contributes to several ongoing projects:

- **NUTRIENT**: quantifying the present and future atmospheric delivery of bioavailable iron to the ocean
- **FRAGMENT**: quantifying the effects of dust mineralogy on climate
- **FORCES**: reducing the uncertainty in anthropogenic aerosol radiative forcing

We thankfully acknowledge the computer resources at Marenostrum4 [granted through the PRACE project eFRAGMENT2 and the RES project AECT-2020-3-0020] and the technical support provided by the Barcelona Supercomputing Center and the Computational Earth Sciences team of the Earth Sciences Department. We further acknowledge the EC-Earth community and the AerChemMIP team.

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